TECHNICAL NOTES

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By John R. Dawson and Starr Truscott
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SUMMARY

A general test was made in the N.A.C.A. tank of a 1/12-size model of the hull of the British Singapore IIC flying boat loaned by the Director of Research, British Air Ministry. The results are given in charts and are compared with the results of tests of a model of an American flying-boat hull, the Sikorsky S-40. The Singapore hull has a greater hump resistance but a much lower high-speed resistance than the S-40.

The results of the tests are also compared with the results from tests of the same model that were made in the British R.A.E. tank and the agreement is found to be close where sufficient data are available to be conclusive.

INTRODUCTION

A model of the hull of the British flying boat Singapore IIC that had previously been tested in the R.A.E. tank at Farnborough has been tested in the N.A.C.A. tank. The tests were suggested by Mr. H. E. Wimperis, Director of Scientific Research, British Air Ministry, who also took the necessary steps to have the model shipped from Ottawa, Canada, where it had been sent from England for comparative tests in the Ottawa tank. The Singapore IIC hull represents a fairly recent British design, and these tests make it possible to compare its performance with the performances of American designs as well as to compare the results of the tests in the two tanks.

This is believed to be the first time that the same model of a flying-boat hull has been tested in two different tanks. The N.A.C.A. tank is of larger cross section

than the R.A.E. tank and usually tows models of larger size to higher speeds than other tanks devoted to seaplane work. If a model that has been tested in a smaller tank is also tested in the N.A.C.A. tank and the results confirm those from the tests in the smaller tank, it may fairly be concluded that the results in the smaller tank have not been affected by the proximity of the walls or the bottom.

THE MODEL

The model is 1/12 size and is shown in the photographs of figure 1. In reference 1 it is referred to as "Hull B" and in the N.A.C.A. tank series it is designated model 58.

The forebody of the model has a rounded keel, arched bottom sections, and terminates in a pointed main step with an included angle of 119°. The angle of dead rise on the forebody is somewhat smaller and the depth of the step is greater than is found in the form of most contemporary American hulls of about the same size. The afterbody has a low angle of dead rise at the main step, but this angle increases rapidly aft of the step until an extremely high angle of dead rise is obtained at the narrow second step with which the afterbody terminates. On the full-size craft a tail appendage, part of which was omitted on the model, extends aft of the second step to carry the tail surfaces.

The principal dimensions and ratios of the model follow:

Over-all length, inches	54.93
Forebody length, inches	27.39
Afterbody length (main step to second step), inches	21.21
Maximum beam, inches	10.80
Depth of main step, inch	.52
Center of gravity forward of step, inches	2.90

Center of gravity above keel, inches	13.25
Angle of dead rise at main step (angle between horizontal and line drawn from chine tangent to keel), degrees	18.5
Angle between keel aft of main step and keel forward of main step, degrees	7.0
Forebody, percent of length to second step	56.4
Maximum beam, percent of length to second step	22.2
Depth of step, percent of beam	4.8

APPARATUS AND PROCEDURE

A description of the N.A.C.A. tank and the towing carriage is given in reference 2. The towing gear described therein has been modified several times and as used in these tests was as described in reference 3.

The model was tested by the general method with the center of moments at the given position of the center of gravity. The resistance, trimming moment, and draft are measured while the model is towed at constant speed, at a fixed trim, and under a constant load. A sufficient number of speeds and loads are used to give data over what is considered to be the practicable range of loading conditions for the model. Enough trims are used to determine the trim that gives minimum resistance (called "best trim") for the whole range of speeds and loads. The general method of testing makes it possible to determine the water characteristics of a hull for a wide range of loading conditions.

The resistance and trim for zero trimming moment may generally be accurately determined from the general test data for the usual range of center-of-gravity positions up to about 60 percent of the get-away speed. This method, however, may not give accurate results at high speeds and light loads because, under these conditions, only a small change in trimming moment is required to produce a large

change in trim. As a result, the trim obtained may be considerably in error and, since the resistance changes rapidly with trim except near the best trim, the resistance for zero trimming moment in the high-speed region is determined with doubtful accuracy.

With positions of the center of gravity that are usually found in American flying boats, the zero-trimming-moment condition is frequently impracticable at high speeds because a dangerously low trim is obtained. It should also be noted that the value of data for the zero-trimming-moment condition at high speeds is questionable because, in general, the aerodynamic moments of the full-size craft will not be zero under the same conditions; the zero-trimming-moment condition merely represents one position of the control surfaces.

Inasmuch as the zero-trimming-moment data were desired for this model for the complete speed range, the model was balanced to bring the center of gravity of the model to the position corresponding to the full size, and the model was then tested free to trim. This test was run with the same constant loads except that the 1-pound load was omitted, and at approximately the same constant speeds that were used in the general test of this model. In addition to permitting the determination of free-to-trim characteristics for a wide range of loading conditions with the center-of-gravity position used, this test augments the data from the general test by giving an additional point for each cross plot of resistance and trimming moment against trim.

As is the usual practice at the N.A.C.A. tank, the air drag of the towing gear was obtained by making runs without the model. This tare resistance was then deducted from the gross resistance to obtain the net air-plus-water resistance of the model. A velocity survey made for the region around the position of the model during the tests showed that the relative velocity of the air in this region is very nearly the same as the speed of the carriage. Exclusive of the interference and scale effects, the air drag of the model contained in the resistance data should be correct for application to full-size craft. When the model does not represent the complete hull, as is the case in the present test, it is, of course, necessary to estimate the difference between the air drags of the complete hull and of the portion tested in the tank before applying the results to take-off calculations.

The air drag of the hull is, however, only a small part of the total (air-plus-water) resistance for the complete craft even near get-away.

In addition to the usual tests an approximate correction for the air drag of the model was obtained by towing the model in air close to the surface of the water. Although the application of this correction is a departure from the usual practice at the N.A.C.A. tank, this procedure was followed in the tests made at the R.A.E. tank with this model and the determination of this additional correction therefore permits a closer correlation of the data from the two tanks. The results are given in figure 2 expressed in the same nondimensional coefficients that are used later in presenting the resistance of the model at best trim.

No corrections are applied to the trimming moments obtained in the tank tests. The present towing gear produces no appreciable aerodynamic effect on the trimming moment and, in order to be consistent with the manner in which the resistance is determined, the aerodynamic moment on the model is included in the trimming moment. This practice differs from that of reference 1 in which the aerodynamic moment of the model is determined and eliminated just as is the model air drag. However, it is only at high speeds, where the trimming moment is small and sufficient controlling moments are easily obtained on most flying boats, that the aerodynamic moment of the hull becomes appreciable.

In the present free-to-trim tests no external moments were applied to correct for the aerodynamic moment on the model. Although the aerodynamic moment is small, the moment required to produce a large change in trim at high speeds is also small and the trims obtained at high speeds should therefore differ from those obtained in the R.A.E. tests.

Photographs were taken at frequent intervals throughout the tests and, upon the completion of the tests, motion pictures were taken of several accelerated runs with a hydrofoil device set to lift the model from the water at a speed corresponding approximately to the get-away speed of the full-size craft.

RESULTS

Test Data

The results of the general test are shown in figures 3 to 9 in which resistance and trimming moment are plotted against speed with load as parameter. Each figure is for one trim, the angle between the horizontal water surface and the straight part of the keel just forward of the main step. The free-to-trim results are shown in figure 10 in which resistance and trim are plotted against speed with load as parameter.

The absolute accuracy of resistance and trimming moment was somewhat better than is usually the case but the relative accuracy was considerably poorer, especially at the very light loads, owing largely to the fact that the forces were approximately one-fifth as large as those usually measured with the existing apparatus. No drafts are given because the accuracy with which this measurement was obtained in these tests was extremely poor.

At low speeds with the heavier loads, part of the deck of the model was under the water when some of the test points were taken, which does not represent a true condition for the complete hull. It occurs at such low speeds, however, that it is inconsequential.

In figure 11 static trimming moment and static draft are plotted against displacement with trim as parameter. These curves, which were obtained experimentally, are useful in calculations of static stability and also permit the easy determination of load water lines. The range of trims and loads used was limited by the submerging of the deck of the model.

Nondimensional Data

In order to reduce the number of variables necessary for presenting the data from the general test, the trim variable is eliminated by determining the trim that gives minimum resistance for each speed and load. The speed, load, minimum resistance, and trimming moment required to obtain minimum resistance are then converted to the following nondimensional coefficients:

Speed coefficient, $C_V = \frac{V}{\sqrt{gb}}$

Load coefficient, $C_\Delta = \frac{\Delta}{wb^3}$

Resistance coefficient, $C_R = \frac{R}{wb^3}$

Trimming-moment coefficient, $C_M = \frac{M}{wb^4}$

where V is speed, ft./sec.

g, acceleration of gravity, ft./sec.^{2}

b, maximum beam of hull, ft.

Δ, load on water, lb.

w, specific weight of water, lb./cu. ft.
(w = 63.5 lb./cu. ft. for the water in the N.A.C.A. tank during these tests)

R, resistance, lb.

M, trimming moment, lb.-ft.

Any other consistent set of units may, of course, be used.

The data converted to these coefficients are shown in figures 12 to 15. In figure 12, C_R is plotted against C_V with C_Δ as parameter, and in figure 13 C_R is plotted against C_Δ with C_V as parameter. Figure 14 shows τ_o, the best trim, plotted against C_V with C_Δ as parameter. Figure 15 shows C_M at τ_o plotted against C_V with C_Δ as parameter.

DISCUSSION OF RESULTS

General.- In the curves of resistance for a trim of

7° (fig. 5) the resistance curve for the 2-pound load crosses the curves for both the 4-pound and the 8-pound loads at high speeds, indicating an increase in resistance with decreasing load under these conditions. This peculiarity is a result of the spray from the step, which strikes the afterbody at light loads and misses it at heavy loads.

Comparison with model of hull of Sikorsky S-40.- A comparison of the results of these tests with those obtained from similar tests of a model of the Sikorsky S-40 hull (reference 4) is shown in figure 16 where C_R at best trim is plotted against C_V for several values of C_Δ. It should be noted that this method of comparison implies that the two models have the same beam at the same load. Inasmuch as the two hulls are of about the same proportions, a comparison on this basis appears to be justified. It is apparent that the S-40 form has a considerably lower hump resistance but at high speeds the Singapore form has a much lower resistance than the Sikorsky form.

The differences in resistance may be explained in part by the fact that the Singapore form has a lower angle of dead rise on the forebody, has a relatively deeper step, and the angle of dead rise of the afterbody increases to a very large value at the relatively narrow second step. These differences tend to reduce the resistance at high speeds, the latter two at the cost of increased resistance at the hump.

COMPARISON OF N.A.C.A. AND R.A.E. TESTS

In any comparison of the results of the tests made in the N.A.C.A. tank with those made in the R.A.E. tank it should be remembered that the towing carriage and towing gear of the N.A.C.A. tank were designed and constructed to be capable of towing models of lengths up to 12 feet at speeds up to 75 or 80 feet per second. For the sake of convenience and economy, the models are usually from 7 to 9 feet in length with loads on the water of from 80 to 100 pounds and get-away speeds of from 40 to 60 feet per second. In the tests of the Singapore model, the N.A.C.A. tank was dealing with an unusually small model, about 4 feet 7 inches long, for which the quantities measured were in the

very lowest part of the range of the capacity of the equipment.

The following comparisons of the results obtained in the N.A.C.A. and the R.A.E. tanks are for a full-size gross load of 27,300 pounds and full depth of water in both tanks. The wing lift was applied according to the lift-coefficient curve given in figure 16 of reference 1. The wing area used was 1,760 square feet. The data for the R.A.E. tank tests are from figures 20, 21, and 25 of reference 1. The aerodynamic moment of the model was deducted for the R.A.E. curves but not for the N.A.C.A. curves. The resistance values for the tests from both tanks were corrected for the air drag of the model. The curves representing the N.A.C.A. tank tests were obtained from figures 3 to 10 by cross-plotting resistance, trimming moment, and trim against load at selected speeds and by determining the values of these variables for the computed loads. In the free-to-trim tests, load and trim are interdependent and the load was determined by either successive approximations or by cross-plotting as was most convenient.

In figure 17 the results of free-to-trim tests from the two tanks are compared. Good agreement was obtained at speeds up to about 40 knots, but at higher speeds both the resistance and trim were considerably smaller for the R.A.E. tank tests. Apparently the difference was caused to a large extent by the aerodynamic moment of the model, the increased trim due to this moment causing an increase in the resistance for the N.A.C.A. tests.

In figure 18 the resistance obtained in the R.A.E. free-to-trim tests is compared with the resistance at the same speeds and trims as derived from the results of the general method tests in the N.A.C.A. tank. This comparison is independent of the difference in trims obtained in the free-to-trim tests from the two tanks and shows excellent agreement except at the hump, where the N.A.C.A. resistance curve is somewhat higher than that of the R.A.E.

It should be noted that this comparison is made for the one condition of loading given in the R.A.E. report of the tests of this model. From this comparison the tentative conclusion can be drawn that tests of a model in the R.A.E. tank show a slightly smaller hump resistance than tests in the N.A.C.A. tank, although there is a possibility

that accumulating errors in both resistance and trim data might account for the difference. It should also be noted that, in order to make a final conclusion, additional data should be available from further tests in the R.A.E. tank at other trims and loads.

A comparison of the resistances obtained in the two tanks at four different speeds and for a range of trims is shown in figure 19. The agreement here is very good. The greatest differences are found at the highest speeds where the loads are small and the accuracy is considerably poorer than at the lower speeds. A similar comparison of the trimming moments at the same speeds is shown in figure 20. At the lower speeds the results agree exceptionally well but appreciable differences are obtained in the region of the highest speeds. These differences are apparently caused mostly by the aerodynamic moment of the model which should, of course, increase with speed.

CONCLUDING REMARKS

The Singapore IIC hull has relatively low resistance at high speeds but the resistance at the hump is high. In general, there is close agreement between the results obtained in the N.A.C.A. tank and those from the R.A.E. tank. The greatest difference in the resistance is at the hump where the data available from the R.A.E. tank are insufficient to allow definite conclusions as to the reason for this discrepancy.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., July 10, 1936.

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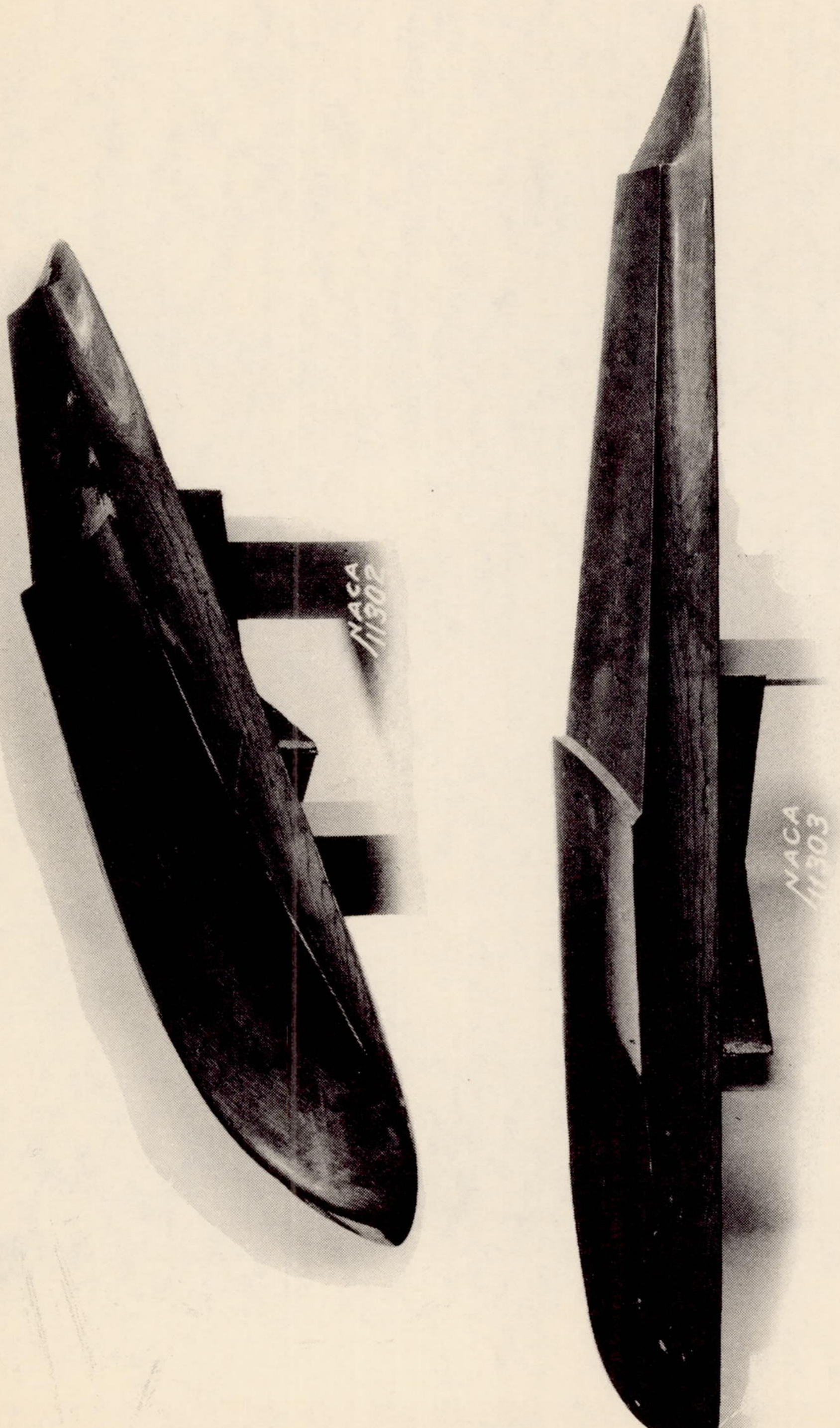


Figure 1.- Photographs of model 58.

$$\Delta C_R = \frac{\text{Air drag of towing gear and model minus air drag of towing gear.}}{wb^3}$$

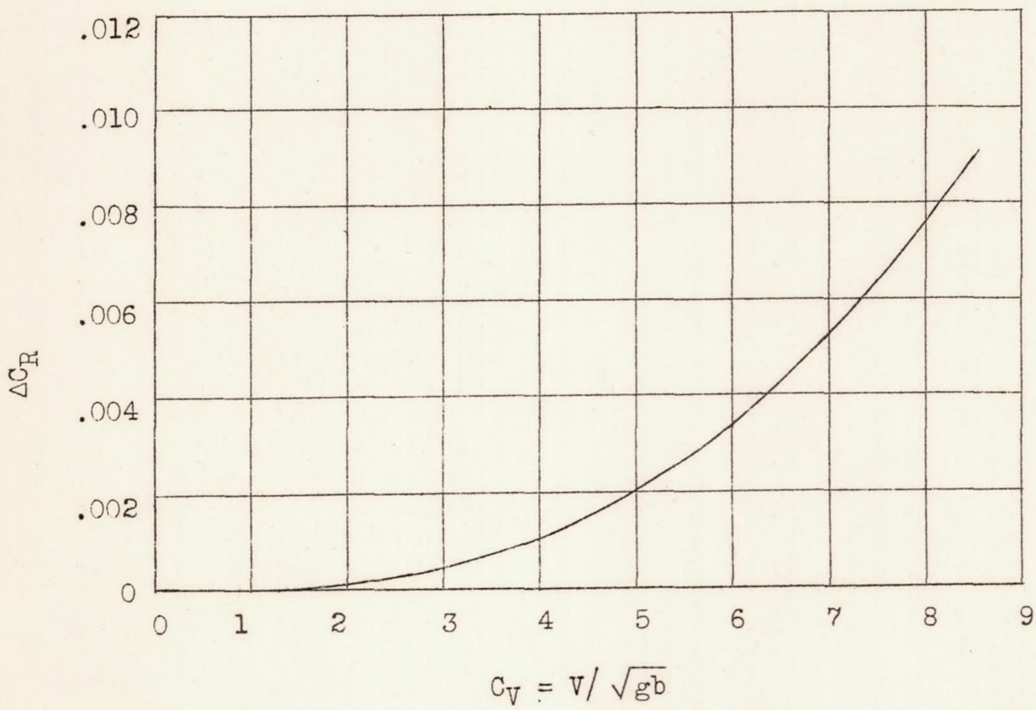
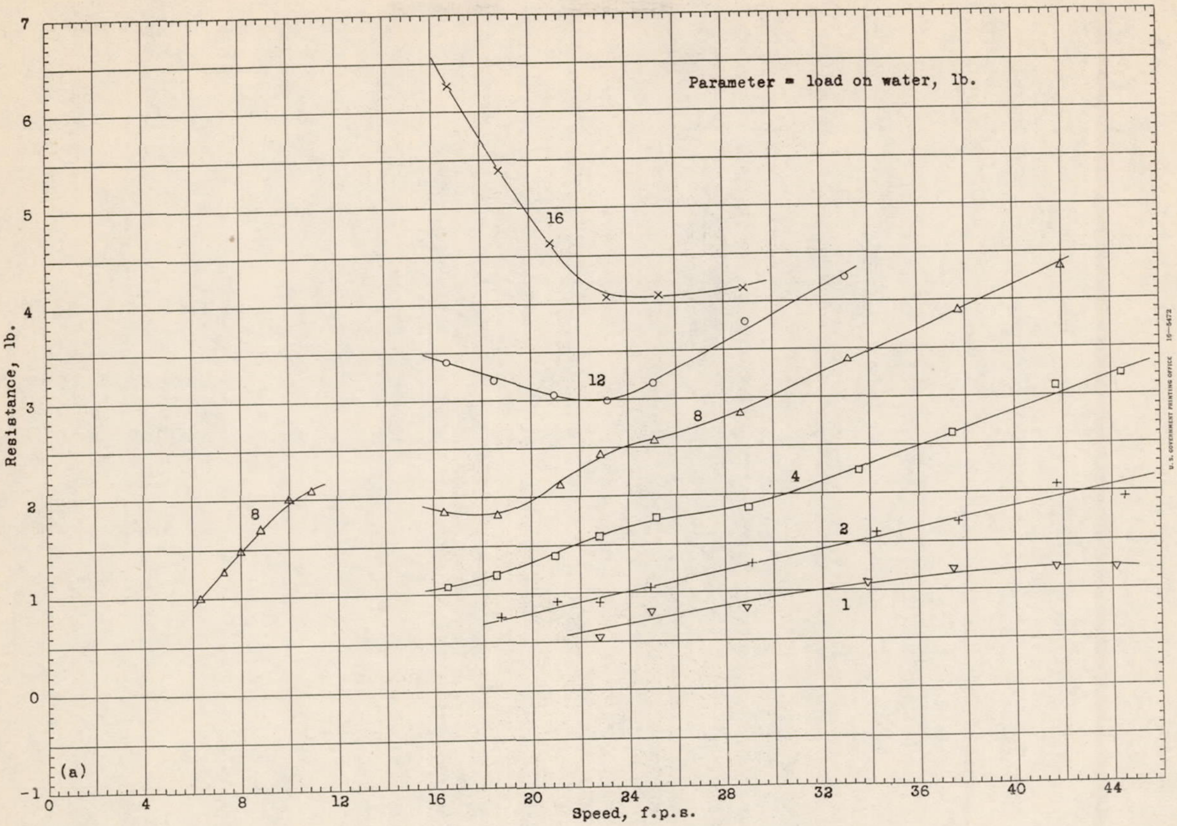


Figure 2.-Air-drag correction for model 58.



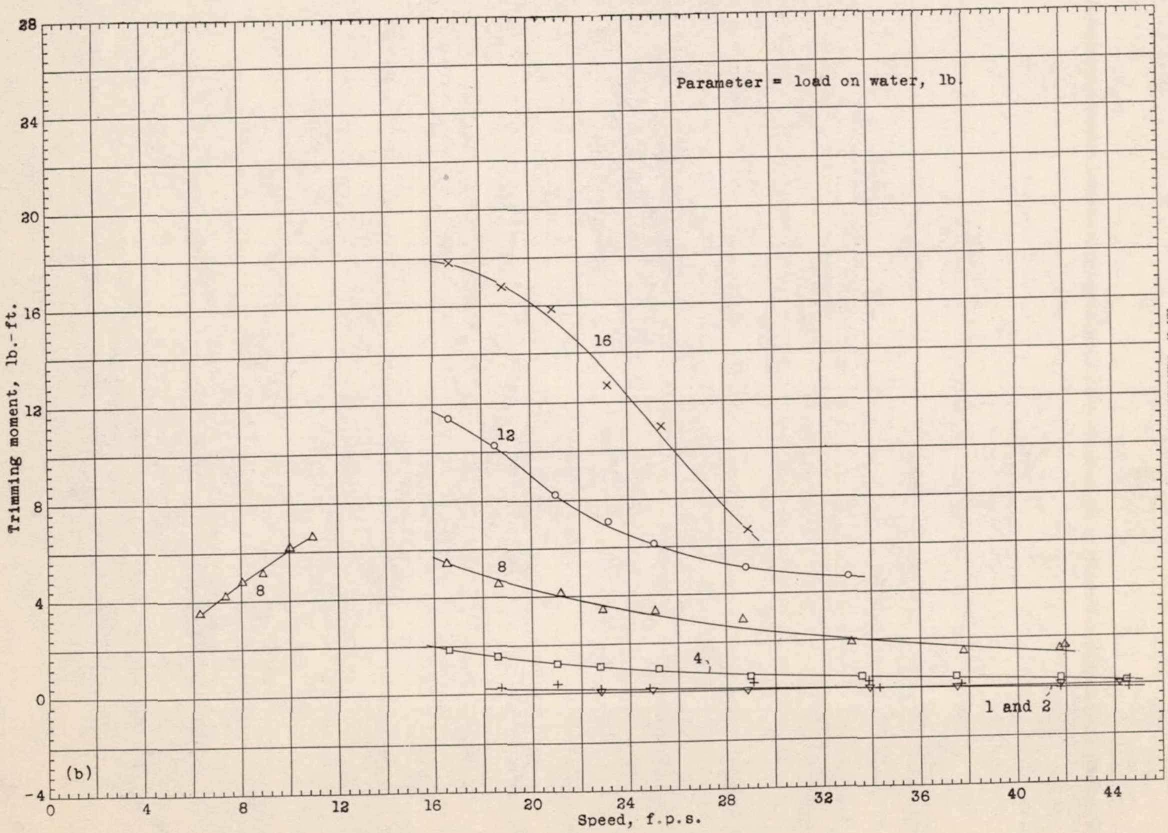
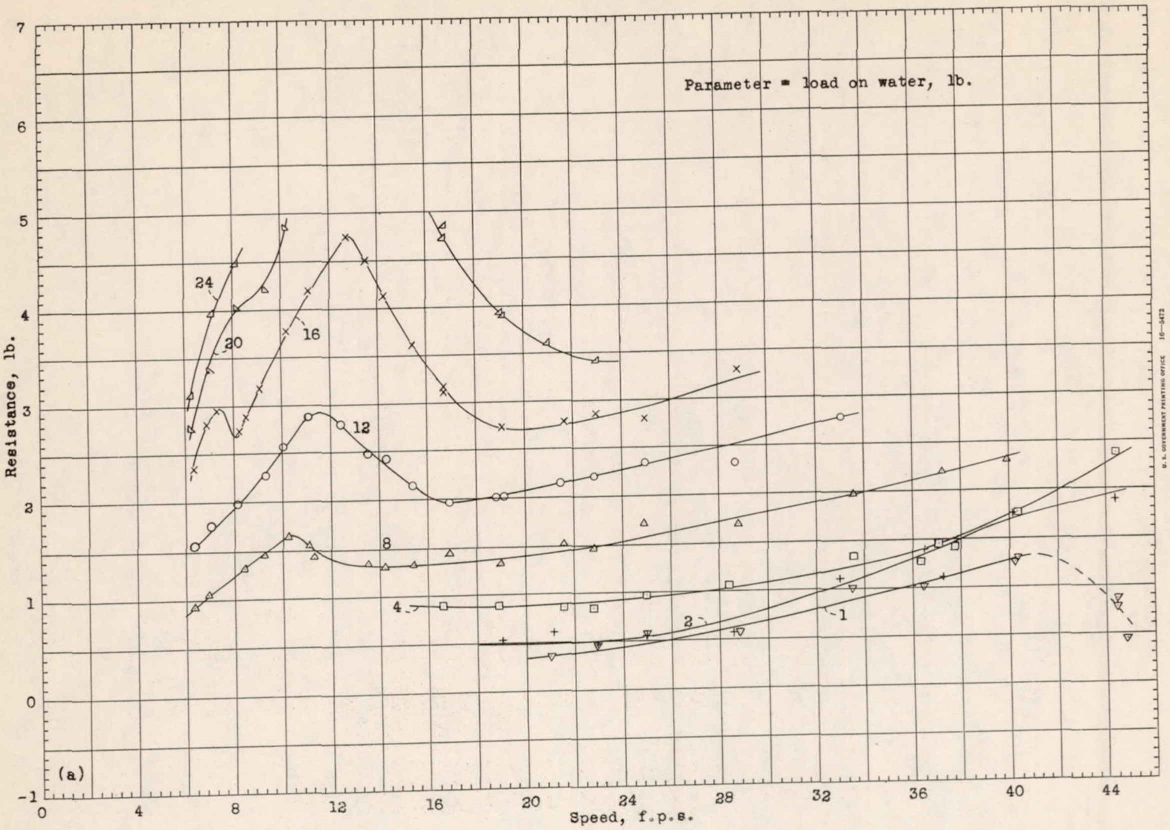


Figure 3.- Model 58. Resistance and trimming moment, $\tau = 3^{\circ}$.



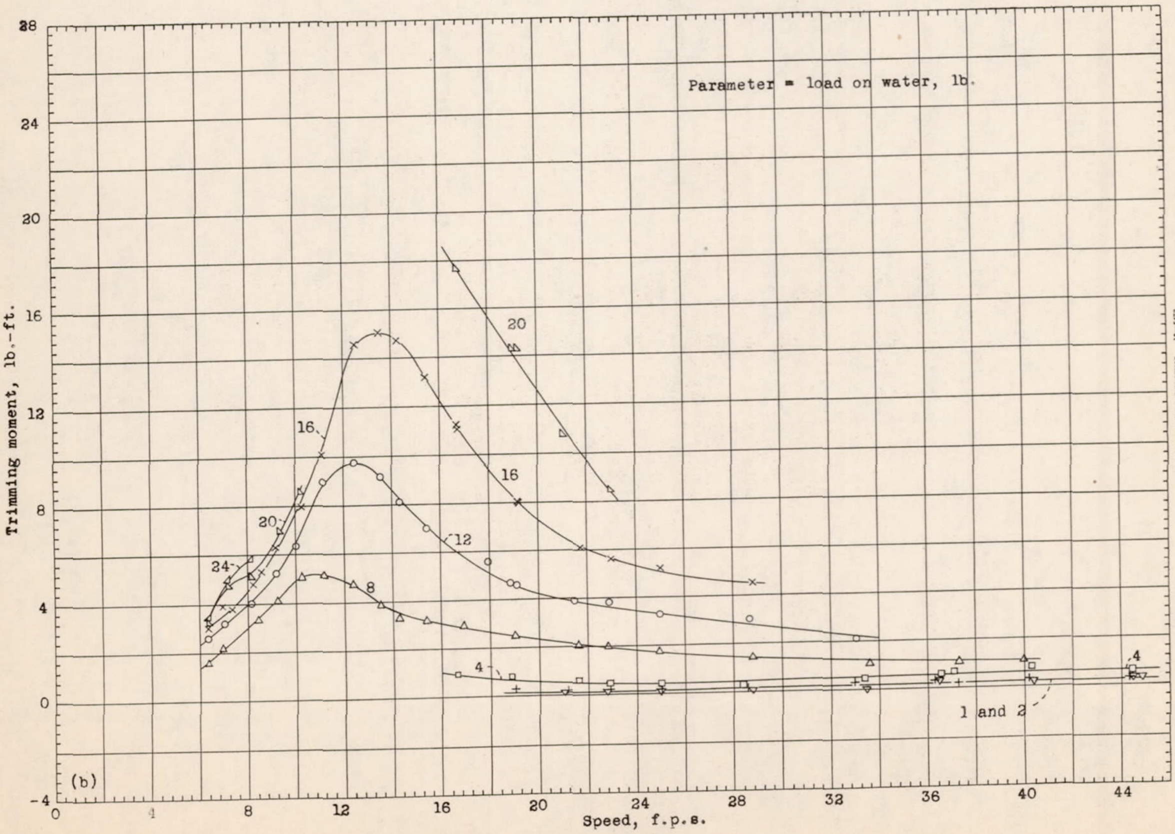
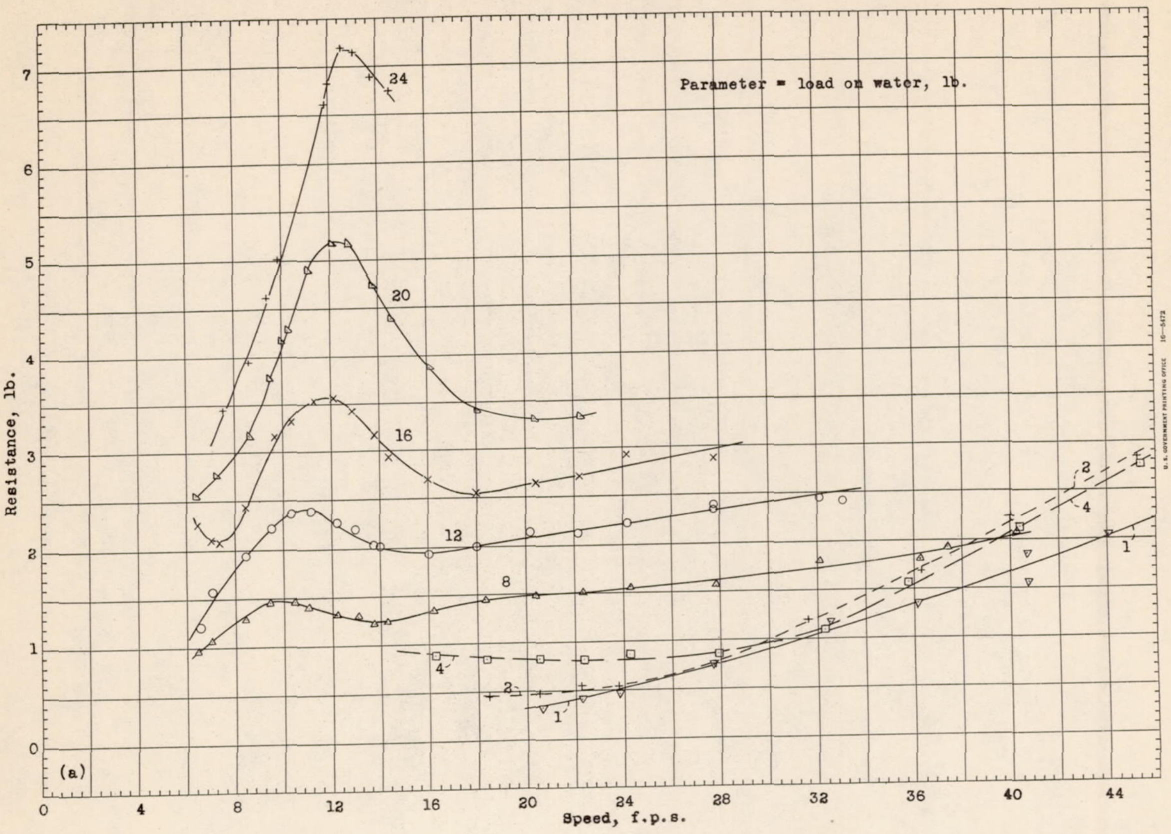


Figure 4.- Model 58. Resistance and trimming moment, $\tau = 5^{\circ}$.



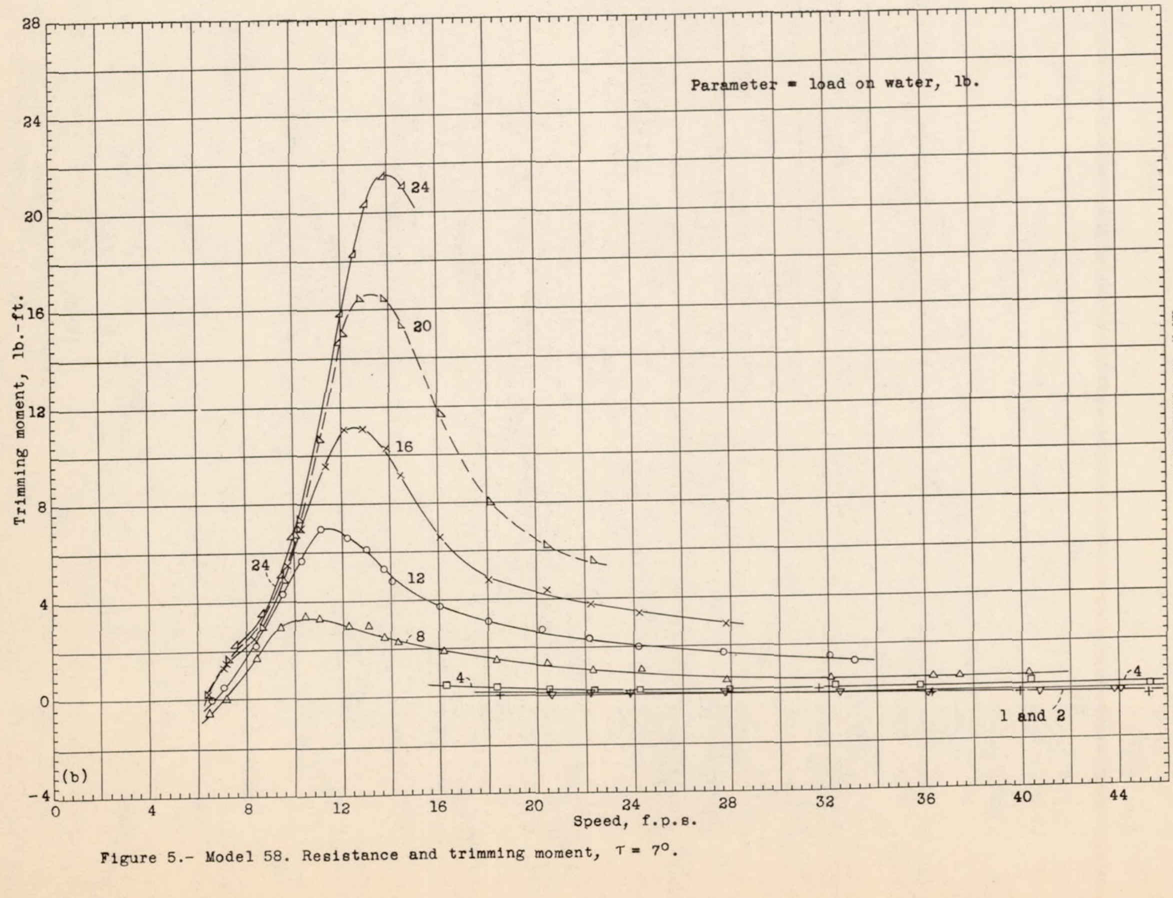


Figure 5.- Model 58. Resistance and trimming moment, $\tau = 7^{\circ}$.

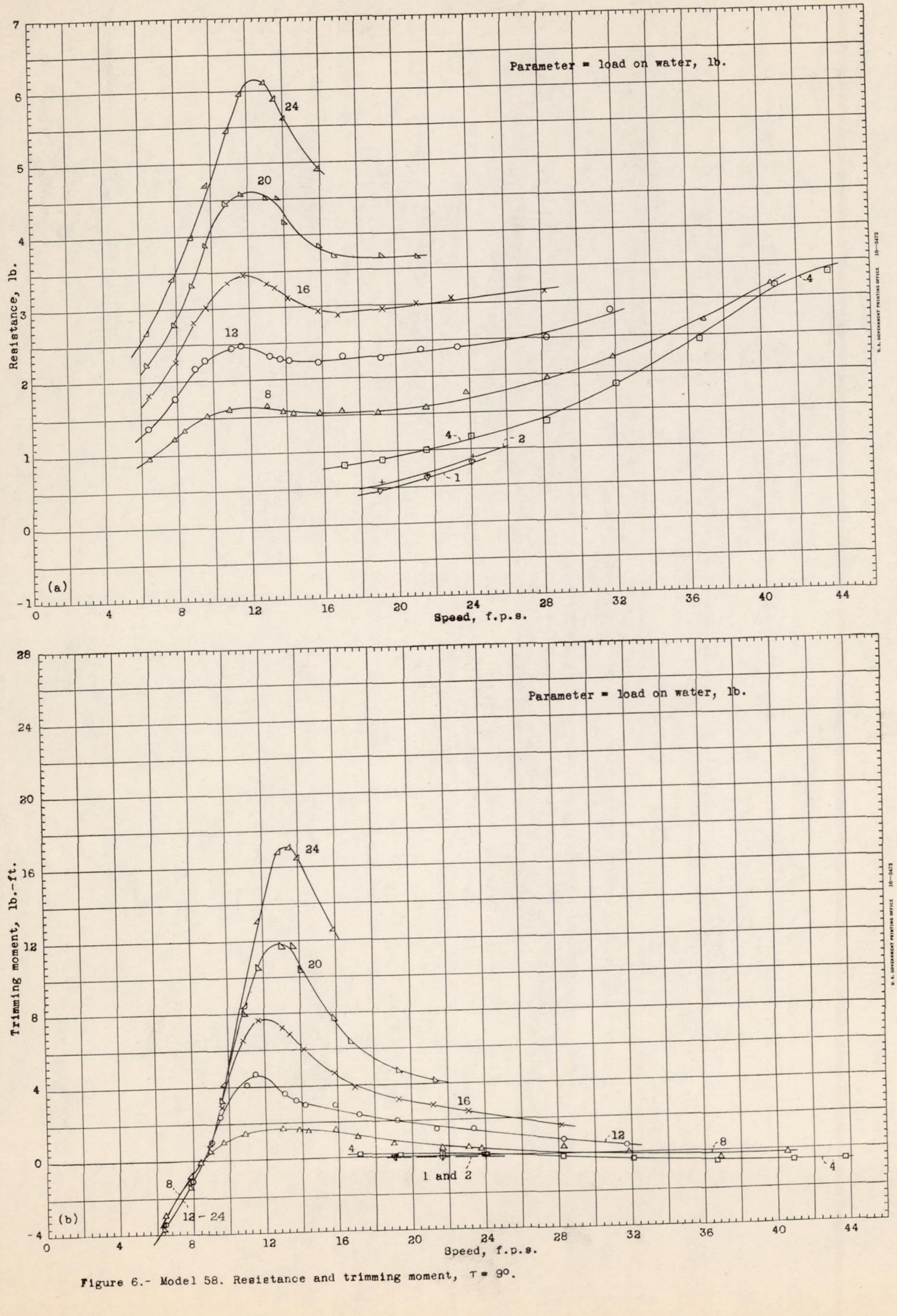


Figure 6.- Model 58. Resistance and trimming moment, $\tau = 9^{\circ}$.

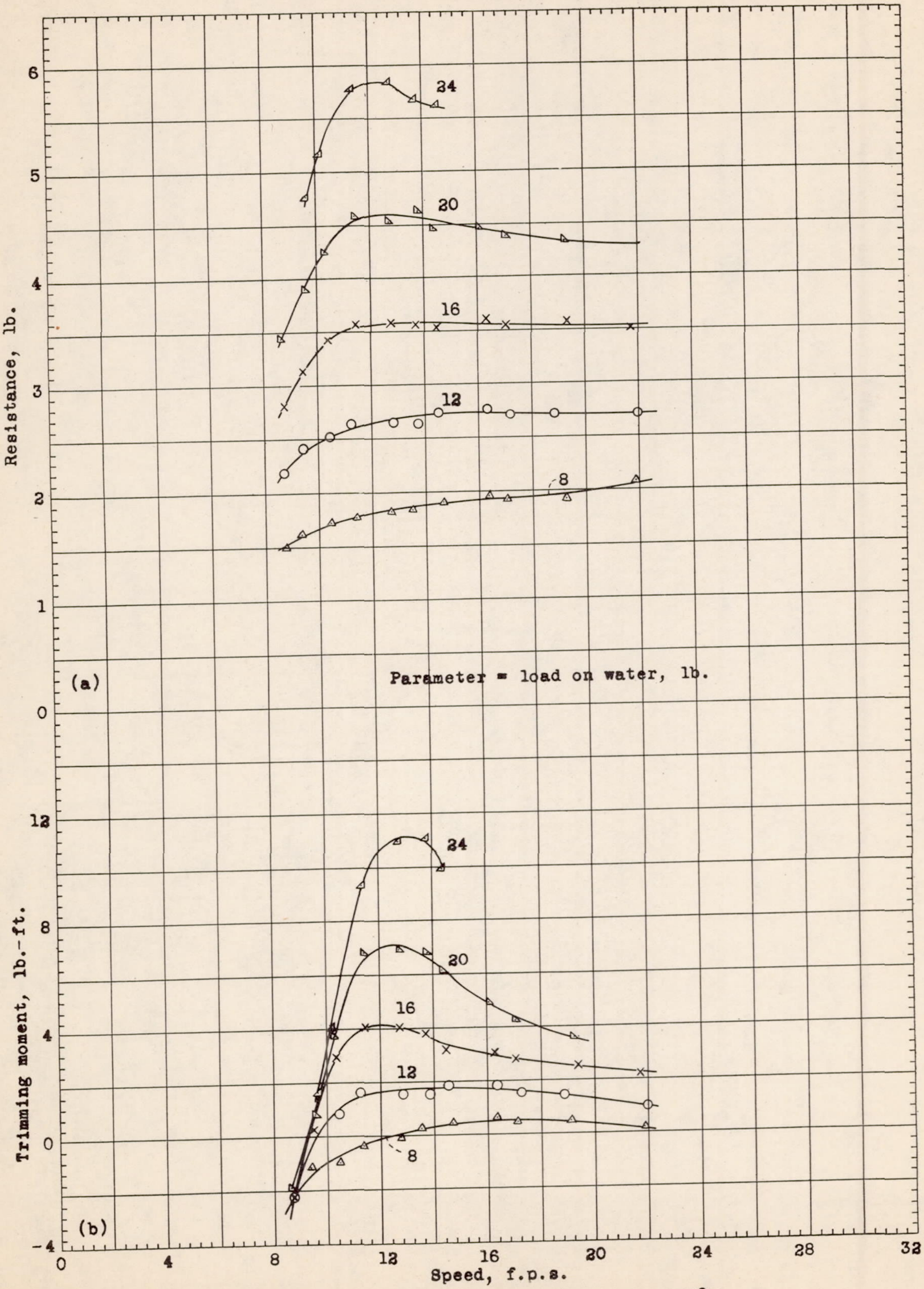


Figure 7.- Model 58. Resistance and trimming moment, $\tau = 11^{\circ}$.

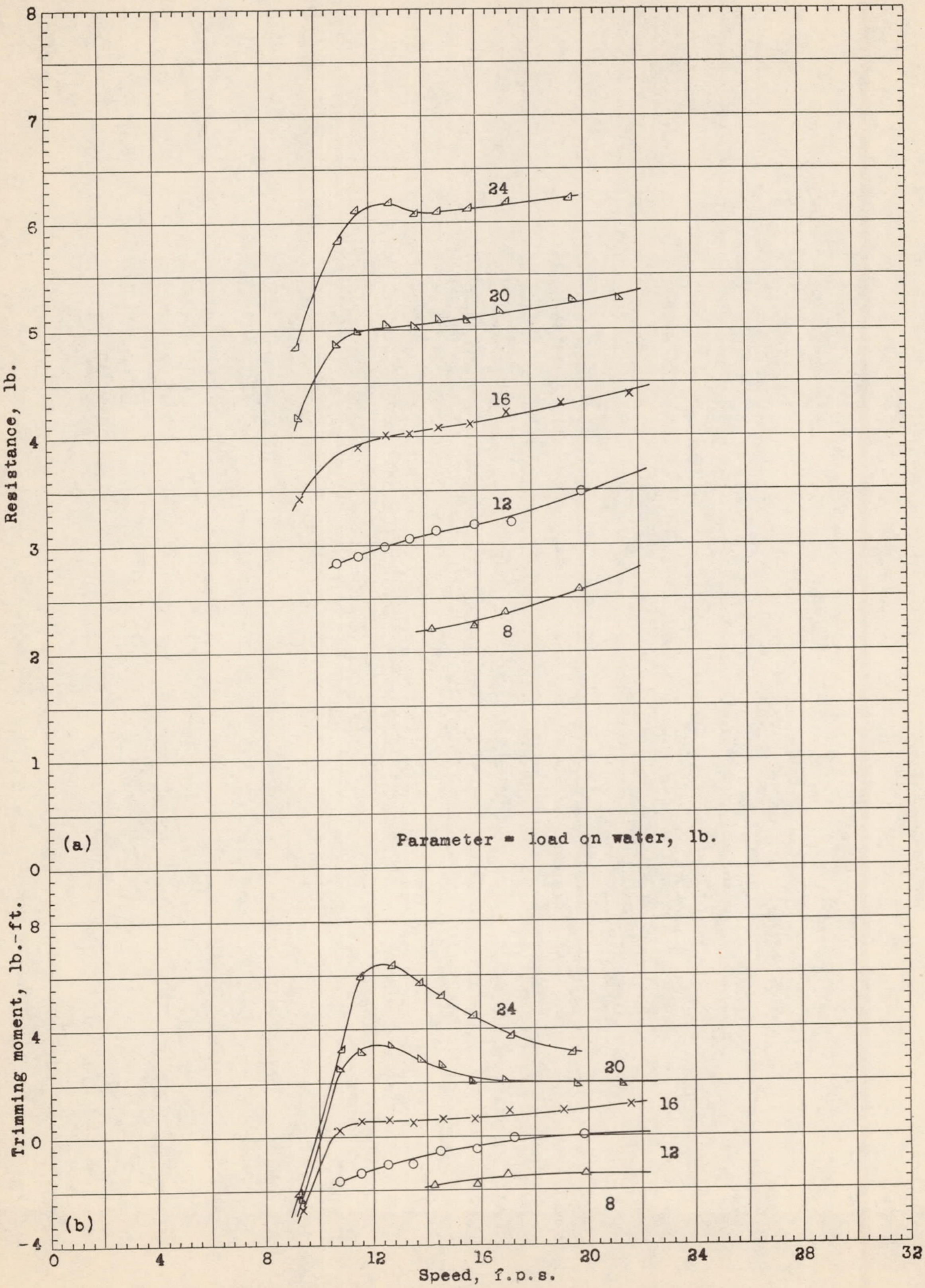


Figure 8.- Model 58. Resistance and trimming moment, $\tau = 13^o$.

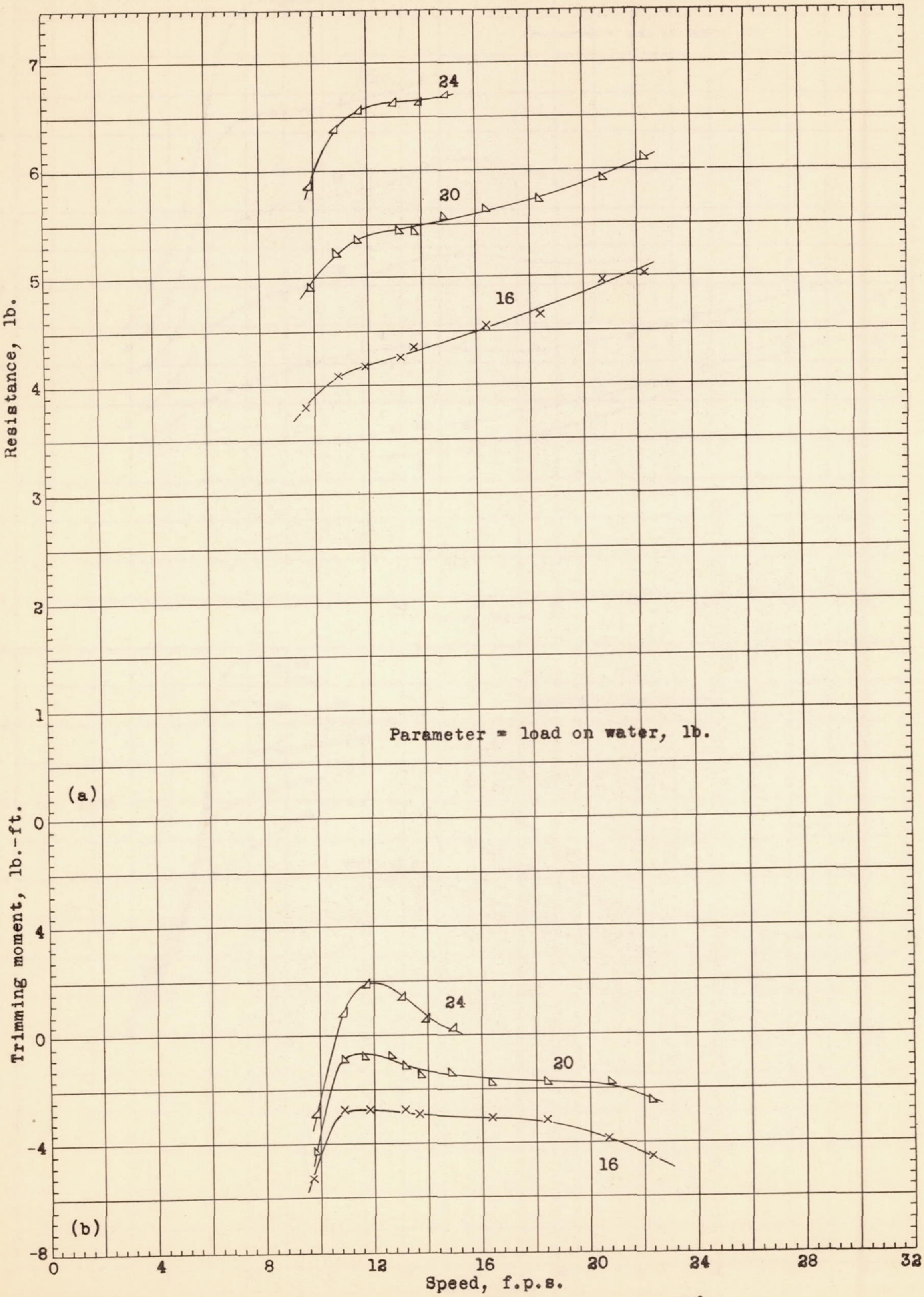
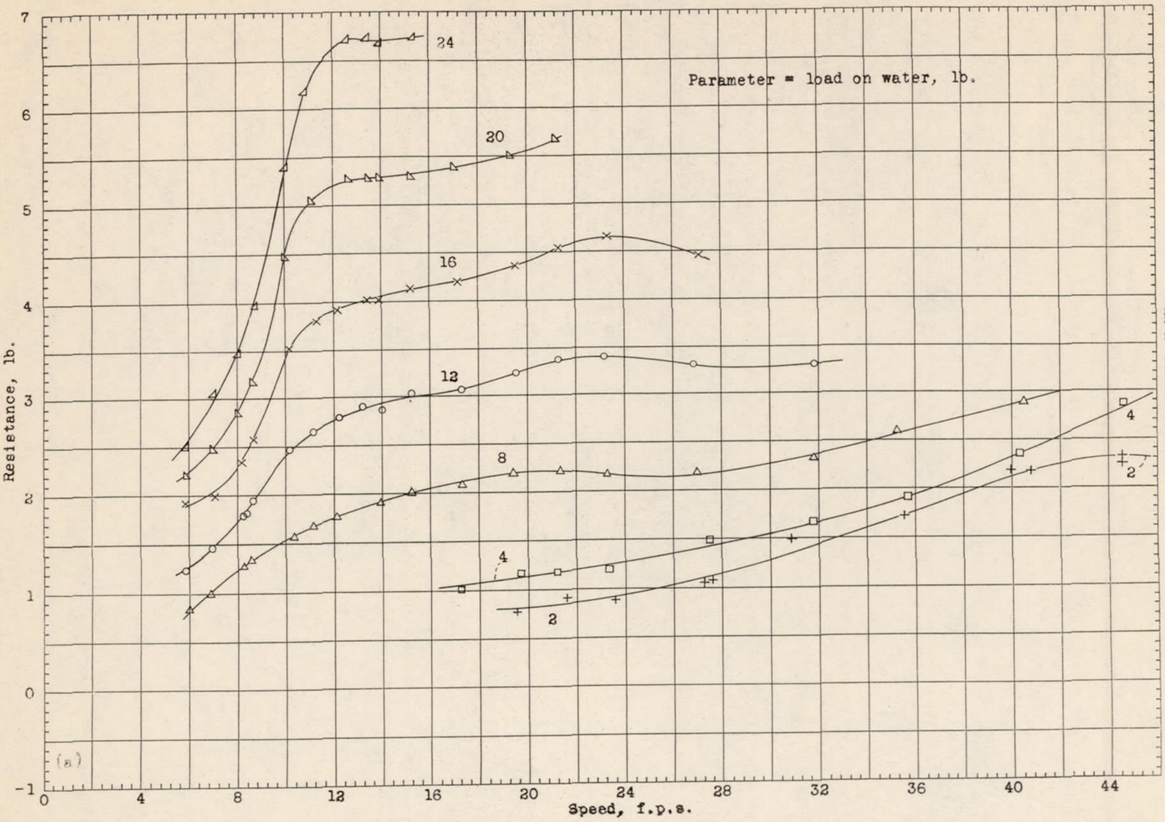


Figure 9.- Model 58. Resistance and trimming moment, $\tau = 15^{\circ}$.



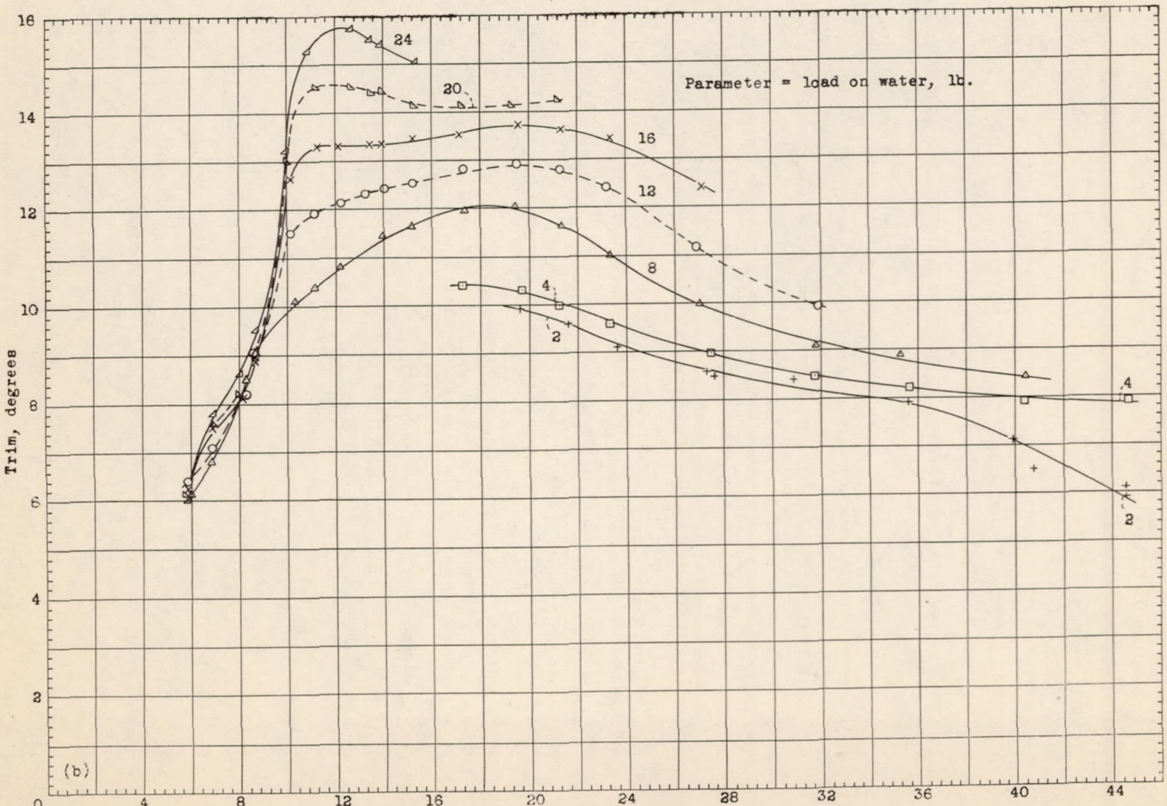


Figure 10.- Model 58. Resistance and trim, free to trim.

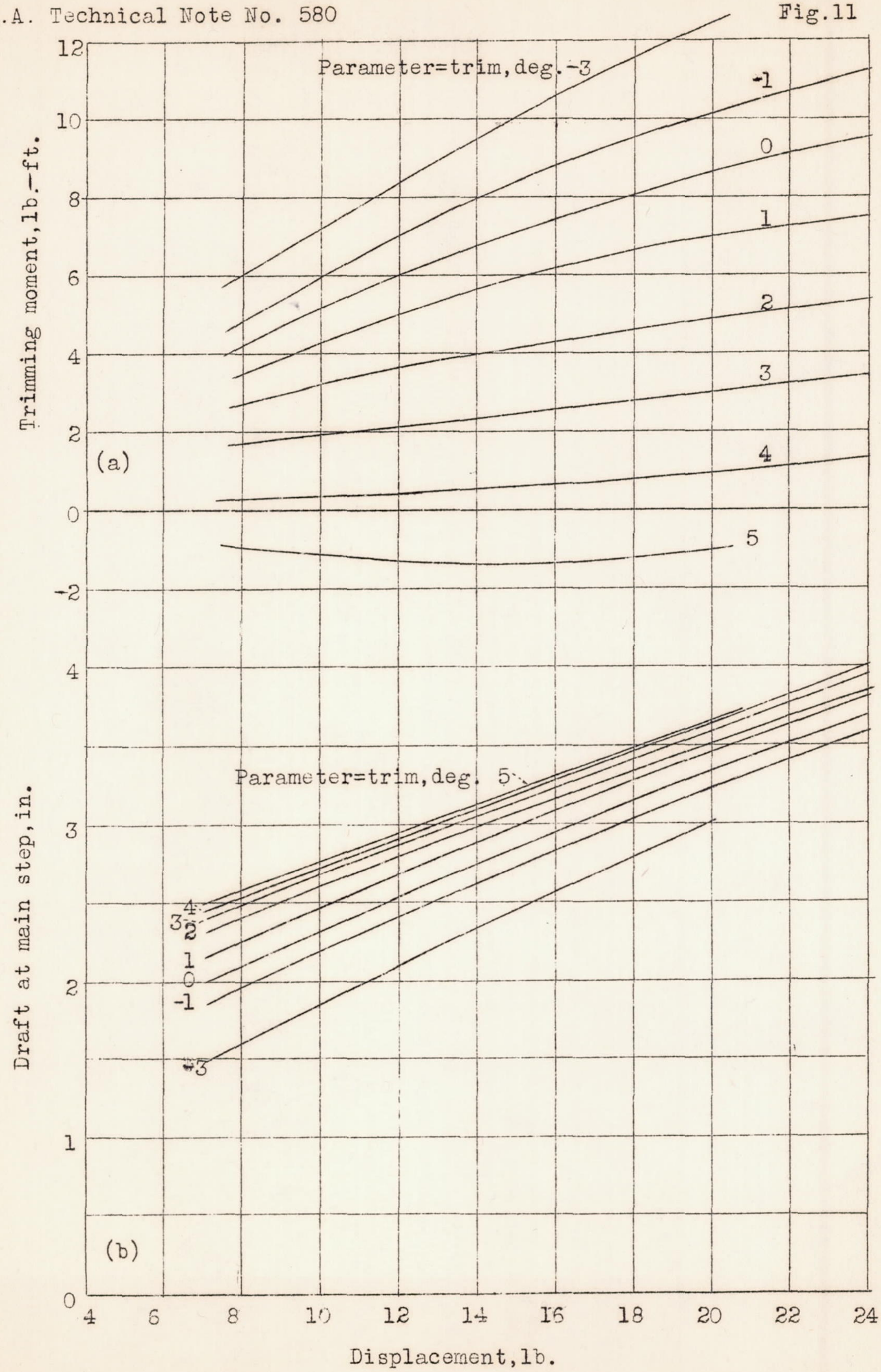


Figure 11.-Static drafts and trimming moments, model 58.

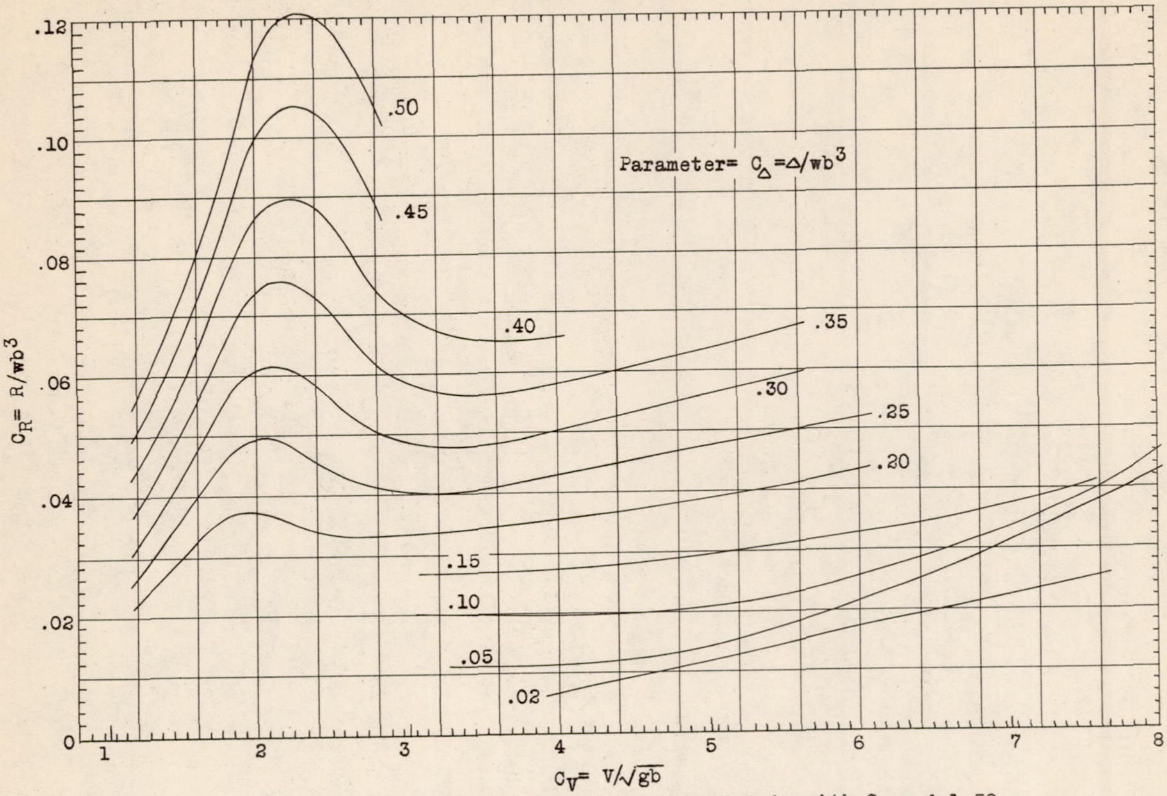


Figure 12.- Variation of C_R at best trim with C_V, model 58.

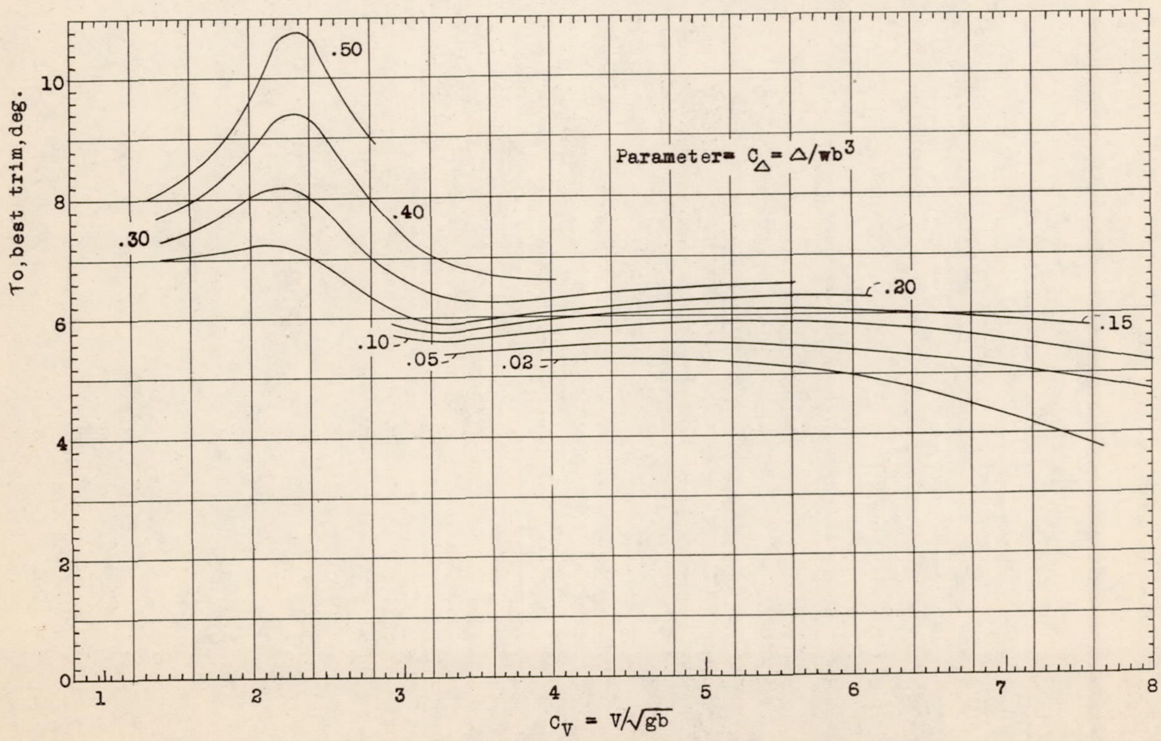


Figure 14.- Variation of best trim with C_V, model 58.

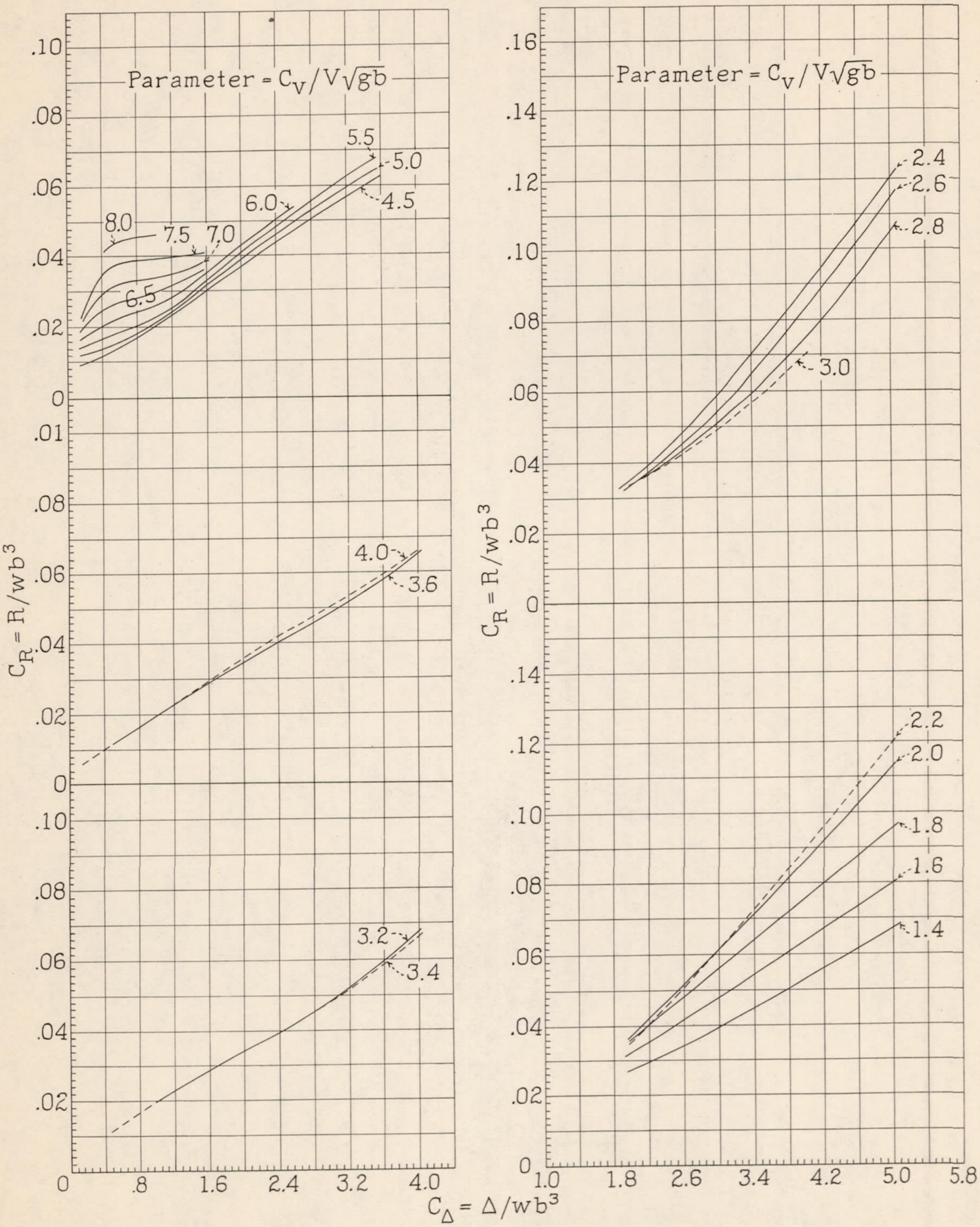


Figure 13.- Variation of C_R at best trim with C_Δ, model 58.

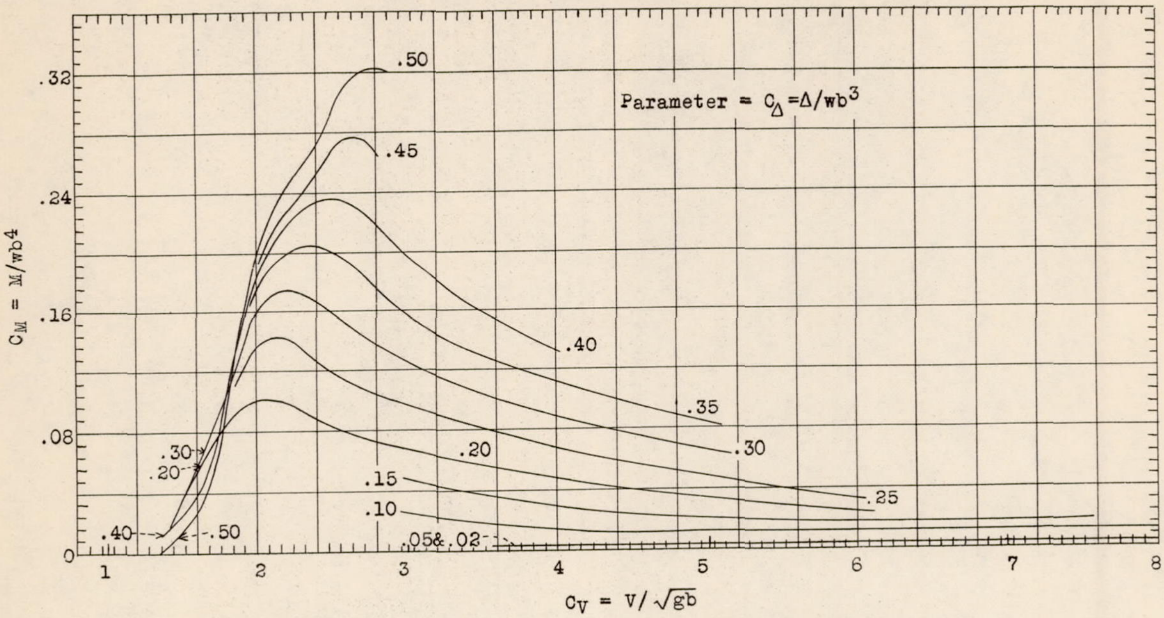


Figure 15.- Varation of C_M at best trim with C_V, model 58.

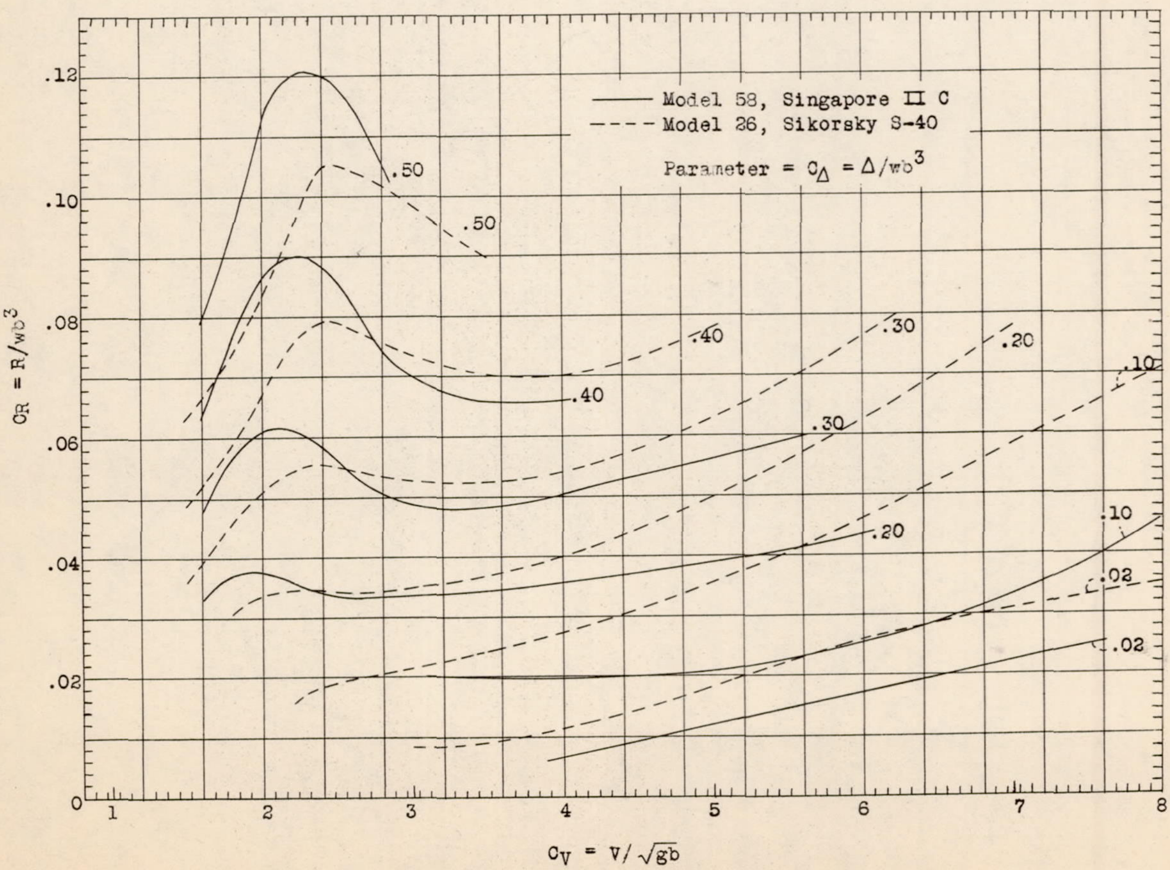


Figure 16.- Comparison of C_R at best trim for models 58 and 26.

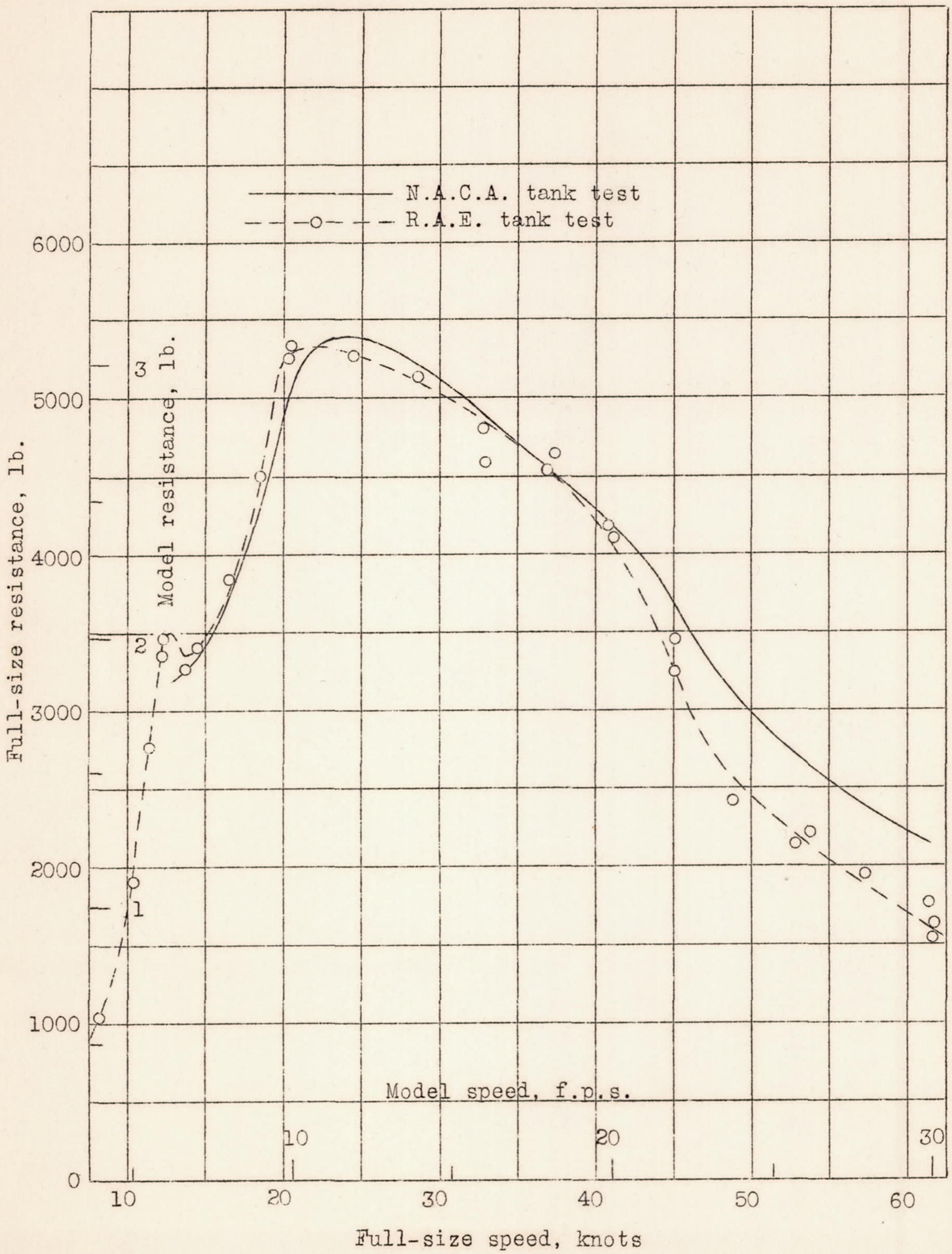


Figure 17(a).- Comparison of free-to-trim results obtained from N.A.C.A. and R.A.E. tanks, model 58.

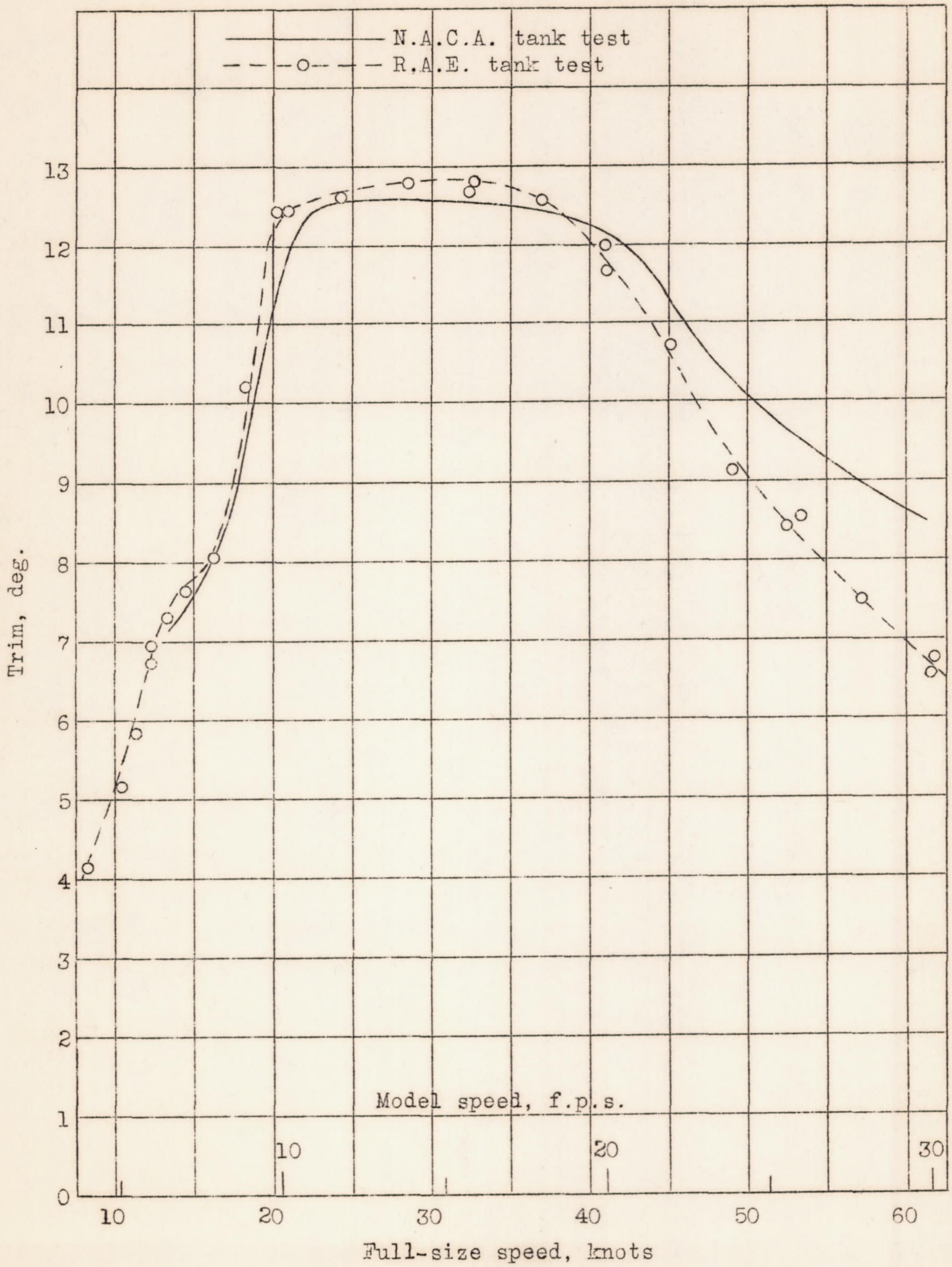


Figure 17(b).- Comparison of free-to-trim results obtained from N.A.C.A. and R.A.E. tanks, model 58.

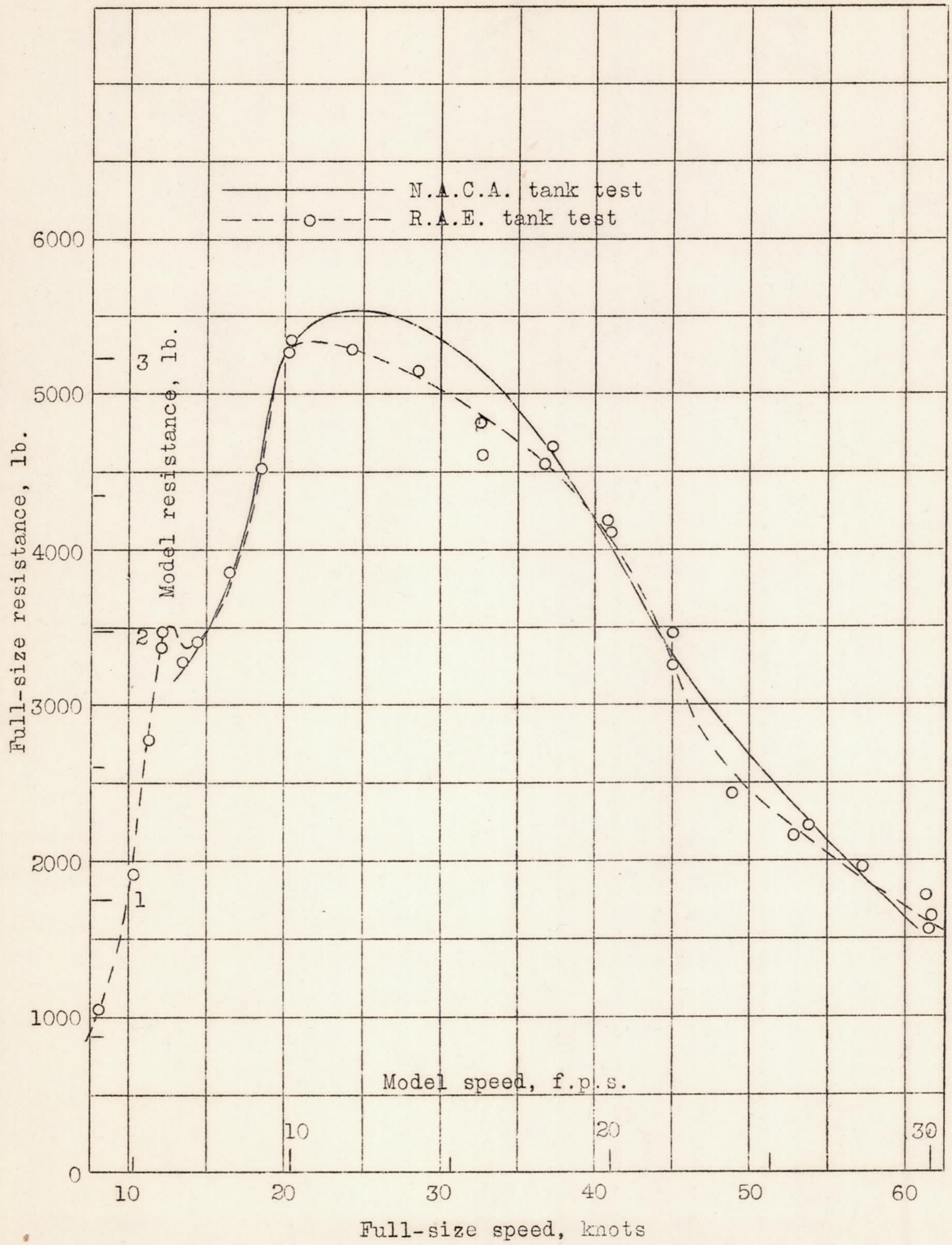


Figure 18.- Comparison of free-to-trim resistance from R.A.E. tank with resistance obtained in N.A.C.A. tank at same trims, model 58.

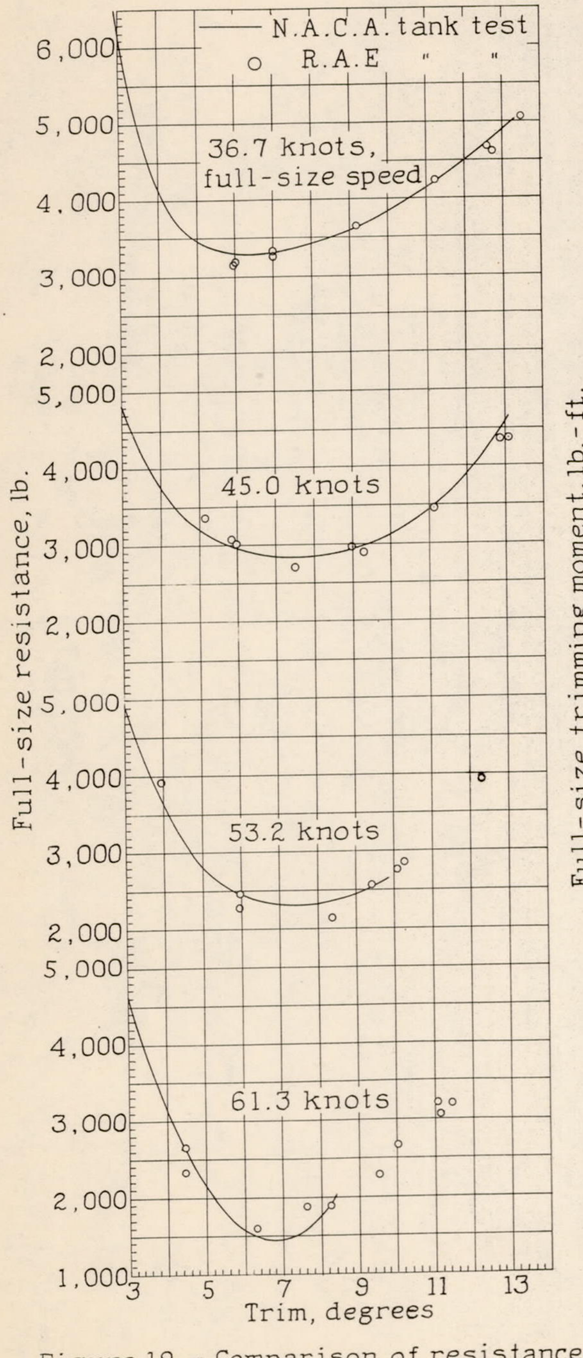


Figure 19.- Comparison of resistance obtained in N.A.C.A. and R.A.E. tanks, model 58.

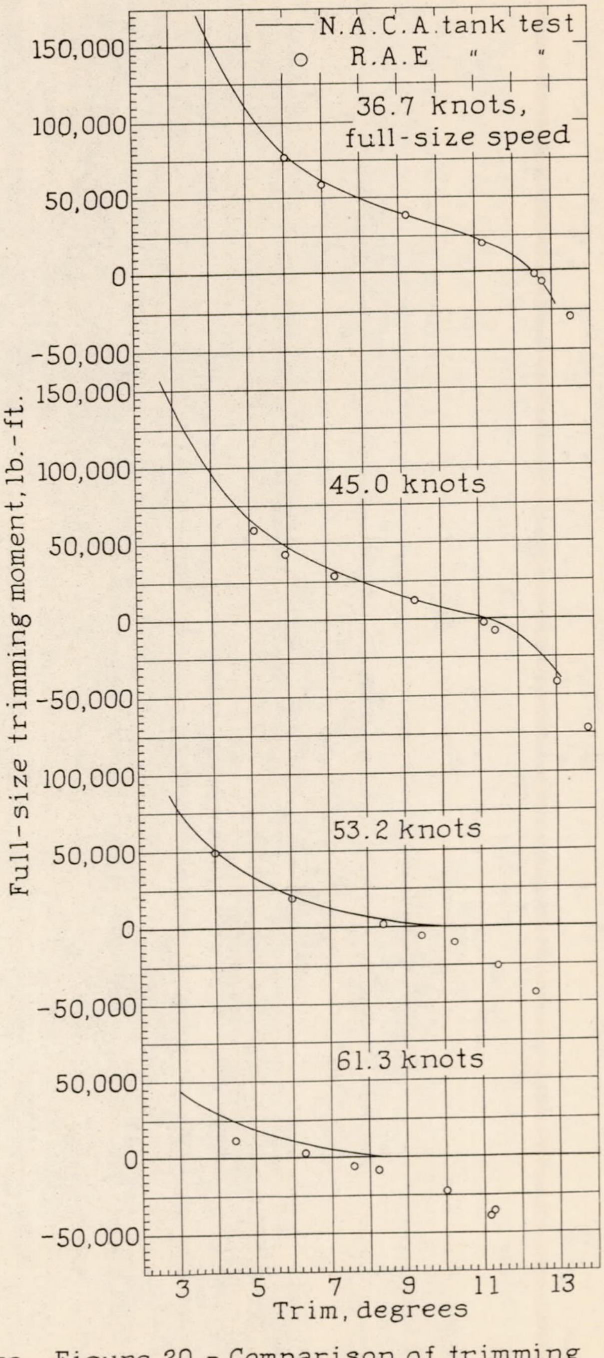


Figure 20.- Comparison of trimming moments obtained in N.A.C.A. and R.A.E. tanks, model 58.